A New Coherent Radar for Ice Sounding in Greenland

A. Moussessian [1], R.L. Jordan [1], E. Rodriguez [1], A. Safaeinili [1], T.L. Akins [1], W.N. Edelstein[1], Y. Kim [1], S.P. Gogineni [2]

[1] Jet Propulsion Laboratory, MS 300-241
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109-8099
Tel: (818) 354-1594, Fax: (818) 393-6943
E-mail: alina@jpl.nasa.gov

[2] The University of Kansas
Radar Systems and Remote Sensing Laboratory
2291 Irving Hill Road
Lawrence, KS 66045
Tel: (785) 864-4835, Fax: (785) 864-7789
E-mail: gogineni@rsl.ukans.edu

ABSTRACT

This paper will discuss a new multifrequency dual channel coherent radar depth sounder for sounding ice. This sounder is unique, since it is a fully coherent chirp radar designed to operate at low (1,500ft) as well as high altitudes (30,000ft). The dynamic range of the radar is sufficient for simultaneously imaging both the top and bottom returns from ice without the need for data blanking or Sensitivity Time Control (STC) equalization of the return signal. The first deployment of this radar on board a P-3 aircraft took place in May of 1999 over Greenland with successful results.

INTRODUCTION

An airborne multifrequency dual channel coherent radar sounder was designed and developed at the Jet Propulsion Laboratory in collaboration with the University of Kansas. The unique feature of this radar sounder is its ability to collect and record coherent digital data at a high Pulse Repetition Frequency (PRF). (A typical PRF of 4KHz was used for most of the data collection). Ice sounding data collected using this high PRF allows us to characterize the backscattering property of the surface and subsurface layers over a wide range of look angles. The measurement of the surface and subsurface backscatter charcteristics are of interest since they determine the optimal focusing technique and consequently, the best resolution which can be achieved for imaging the various components of the ice sheet.

Current radar sounders are designed to operate at low altitudes to avoid surface clutter problems when detecting the subsurface return. One of the objectives of this radar was to demonstrate the feasibility of collecting high altitude ice sounding data similar to spaceborne radars to be flown to Mars and Europa. Due to the high dynamic range of this radar no STC (Sensitivity Time Control) was required for data blanking.

The first deployment of this radar took place in May of 1999 in Greenland. During this deployment we collected data at multiple altitudes and pulse widths at different sites to study the ability of detecting subsurface structures in the presence of surface clutter at high altitudes. We also studied the effects of the azimuth compression on the clutter signal by comparing the low and high altitude data.

In this paper we provide the system overview for the radar sounder used in the data collection in Greenland.

SYSTEM DESCRIPTION

This sounder is a dual channel pulsed chirp radar with frequency tuning capability from 27.5MHz to 150MHz. The frequencies of operation are 35MHz, 50MHz, 60MHz, 75MHz and 150MHz, each with a chirp bandwidth of 15MHz. However during the Greenland deployment the radar was operated only at 150MHz using the University of Kansas antenna system [1].

Fig.1 is the block diagram of the radar sounder. The radar was designed and constructed at JPL except the data acquisition system and the controller unit of the radar, which was developed by the University of Kansas.

A Dayton-Granger 720061 whip antenna was installed at the tail of the aircraft and was used as a transmit antenna. The University of Kansas antennas that were installed under the wings were used as the receive antennas [1].

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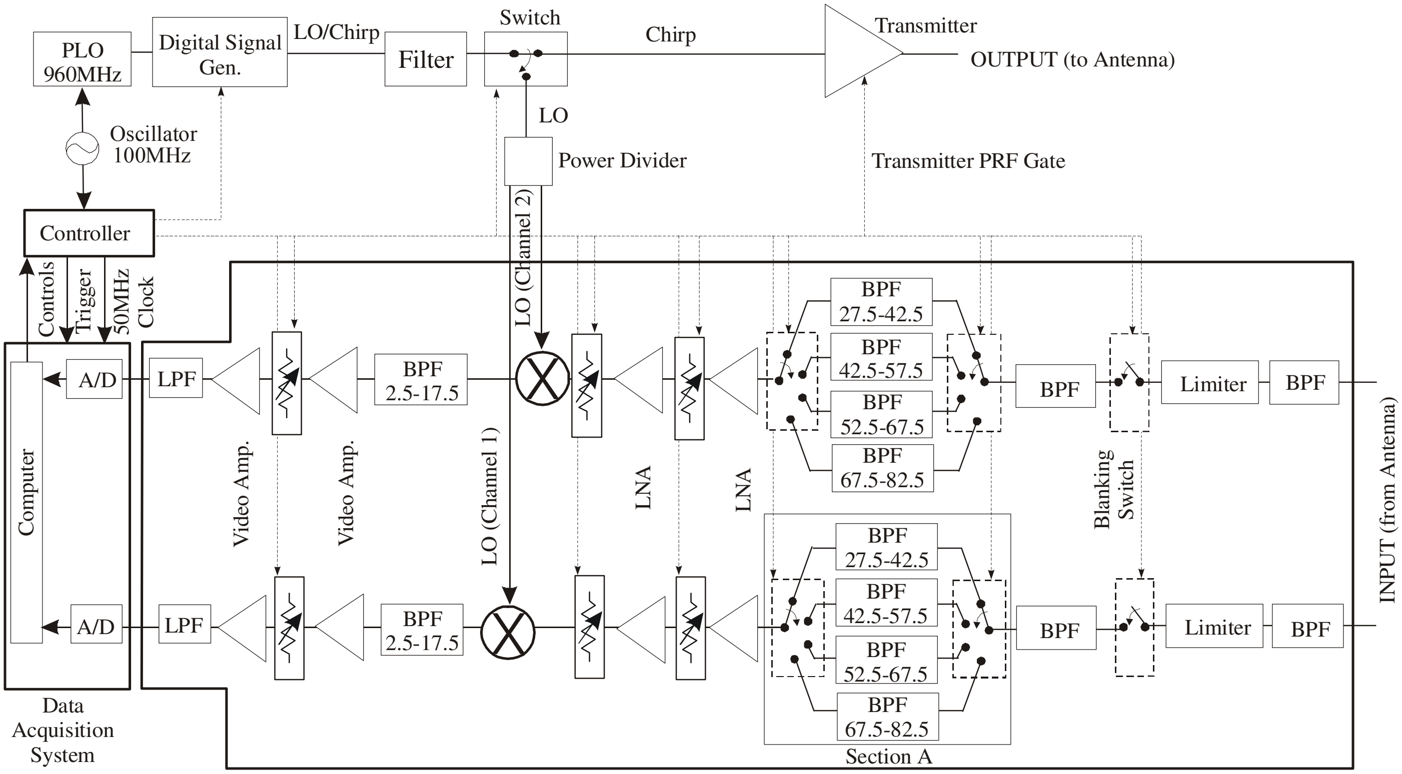

Fig. 1: The block diagram of the radar sounder.

A Stanford Telecom Digital Signal Generator test fixture (STEL-2375STF) using the STEL-2375 Direct Digital Synthesizer (DDS) chip was used to generate both the transmit chirp and the LO for the receiver. The blanking switch and the limiter at the input of the receiver is to protect the radar during transmission and also from possible high power inputs generated by the aircraft communication system. A filter bank at the input selects the corresponding input filter depending on the frequency of operation. There are four filters for each of the lower frequency bands. The 150MHz band was a later addition to the sounder, therefore for operation at 150MHz Section A in Fig.1 is bypassed using a 150MHz filter not shown in the block diagram. The input signal to the receiver is downconverted to a baseband signal from 2.5MHz to 17.5MHz. The receiver has gain control capability in 1dB steps up to 70dB of maximum gain. The radar PRF, pulse width and sampling period is fully adjustable through the software. The most stringent operating conditions were expected when operating at low altitudes. The expected specular signal to noise ratio exceeds 70dB requiring the use of a 12 bit Analog to Digital converter. After pulse compression and digital filtering, the potential dynamic range is of the order of 100dB. Table 1 summarizes the radar parameters.

Table 1: Radar parameters.

Center Frequency	35, 50, 60, 75, 150MHz
Chirp Bandwidth	15MHz
Peak Transmit Power	200W at 150MHz 500W at other bands
Pulse Width	100ns to at least 50µs
PRF	Selectable to at least 4kHz
A/D Dynamic Range	12 bit
Sampling Period	Maximum of 4000
Dynamic Range	100 dB nominal
Depth Resolution	10 meters
Spatial Resolution	20 x 200 meters

RESULTS

Fig.2a shows an example of a 1µs chirp received by our system over Greenland. In this example, the received chirp is mainly due to the specular return from the first interface and as a result the envelope of its spectrum, as shown in Fig.2b, can provide a good estimate for the overall frequency response of our system.

The return from the surface and interior layers was observed to be strongly specular and coherent for most cases, indicating that very little is to be gained from forming long synthetic apertures to image these features. On the other hand, the return from the bottom layer was observed to be incoherent, which indicates that a substantial enhancement relative to the surface return should be achieved by forming long synthetic apertures.

We were unable to detect the ice bottom or any interior surface structure from the data collected at high altitudes and long pulse lengths (30µs). This is because the surface return remained coherent over many pulses, so the sidelobe contamination was not reduced by coherent averaging. This indicates that in the case of long pulses sidelobe levels are the limiting factor in the detection of the subsurface.

A more detailed discussion of the data processing of the Greenland data is presented in [2].

CONCLUSION

The radar was able to penetrate to depths of over 2km, and detailed internal layer structures were observable in the processed data. The dynamic range of the radar was sufficient for simultaneously imaging both the top and bottom returns without the need of data blanking or STC equalization of the return signal.

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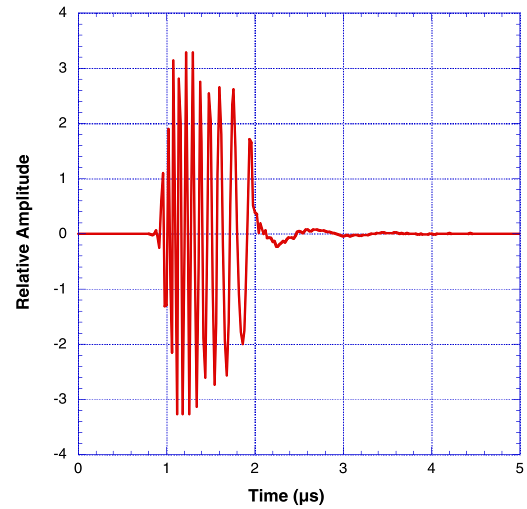
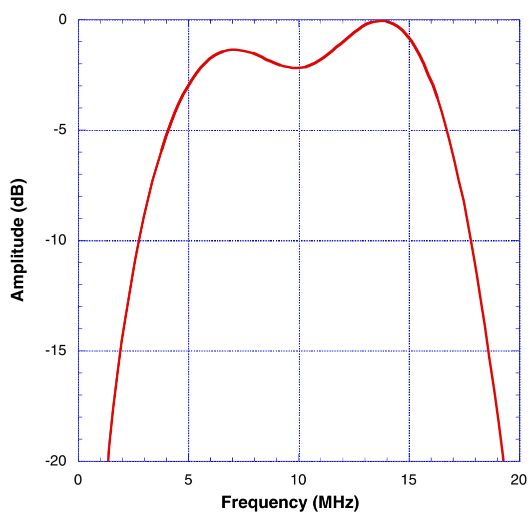


(a)



(b)

Fig. 2: An example of the received signal: a) 1 µs chirp, b) spectrum of the received chirp.